Controlled electron injection from wake shaping using co-propagating laser pulses

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We introduce a novel method of controlled electron injection for Laser Wakefield Acceleration (LWFA) operating in the high-intensity bubble regime. In this multi-pulse scheme, the plasma acts to couple [1] a high-intensity "driver" pulse to a phase controlled, low power "satellite" pulse co-propagating off-axis [2]. The satellite is tightly focused such that it perturbs and drives a transient, asymmetric plasma wave before quickly depleting. Doing so allows for manipulation of the electron phase space, creating a trigger to overcome the wave-breaking injection threshold and leading to efficient particle trapping and acceleration. Supported by 2D and 3D Particle-in-Cell (PIC) simulations using OSIRIS [3], we demonstrate systematic investigation of the two-beam parameter space (e.g. relative temporal delay, beam displacement, etc.) leads to control over electron beam pointing, charge, and emittance. Results indicate this technique could be used to induce self-injection in wakefields at plasma densities and driving laser intensities well below theoretical predictions using satellites of less than 1% the driver energy. Further scaling to additional co-propagating pulses proves to distort the initial plasma wave formation in a predictable manner for near arbitrary wake-shaping. This allows for an ad hoc spatiotemporal setup to control the initial momentum space of injected electrons, leading to a route for enhanced and polarized betatron oscillations. The results show promise for an all-optical knob to transition between a high charge, mono-energetic, GeV particle accelerator and an enhanced x-ray source from betatron radiation through only independent tuning of the low-power satellite.

Acknowledgments

This work is supported in part by the U.S Department of Energy Office of Science under Award No. DE-SC0020070 and AFOSR Grant No. FA9550-19-1-0072

References

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